4 Integrating urban heat assessment in urban plans

Article 3: Integrating urban heat assessment in urban plans. Published in Sustainability 8 (4), 320, 2016; doi:10.3390/su8040320 (http://www.mdpi.com/2071-1050/8/4/320)

Leyre Echevarría Icaza[1]*, Andy van den Dobbelsteen[2] and Frank van der Hoeven[3]

1 Delft University of Technology. Faculty of Architecture and the Built Environment. Address: Julianalaan 134, 2628 BL Delft, The Netherlands; E-Mail: L.EchevarriaIcaza@tudelft.nl

2 Delft University of Technology. Faculty of Architecture and the Built Environment. Address: Julianalaan 134, 2628 BL Delft, The Netherlands; E-Mail: a.a.j.f.vandendobbelsteen@tudelft.nl

3 Delft University of Technology. Faculty of Architecture and the Built Environment. Address: Julianalaan 134, 2628 BL Delft, The Netherlands; E-Mail: F.D.vanderHoeven@tudelft.nl

* Author to whom correspondence should be addressed; E-Mail: L.EchevarriaIcaza@tudelft.nl; Tel.: +34 619 80 32 71

Abstract

The world is increasingly concerned with sustainability issues. Climate change is not the least of these concerns. The complexity of these issues is such that data and information management form an important means of making the right decisions. Nowadays, however, the sheer quantity of data is overwhelming; large quantities of data demand means of representation that are comprehensible and effective. The above dilemma poses questions as to how one incorporates unknown climatologic parameters, such as urban heat, in future urban planning processes, and how one ensures the proposals are specific enough to actually adapt cities to climate change and flexible enough to ensure the proposed measures are combinable and compatible with other urban planning priorities.

Conventional urban planning processes and mapping strategies are not adapted to this new environmental, technological and social context. In order come up with more appropriate urban planning strategies, in its first section this paper analyses the role of the urban planner, reviews the wide variety of parameters that are starting to be integrated into the urban planners practice, and considers the parameters (mainly land surface temperature, albedo, vegetation and imperviousness) and tools needed

for the assessment of the UHI (satellite imagery and GIS). The second part of the study analyses the potential of four catalysing mapping categories to integrate urban heat into spatial planning processes: drift, layering, game-board, and rhizome.

Key words:

mapping; urban planning; urban design; climate adaptation, urban heat; urban heat island

§ 4.1 Introduction

There seems to be a clear mismatch between existing urban planning tools and the actual urbanisation processes (Corner, 2002). Corner refers to urbanists such as Banham, Soja, Harvey, Koolhaas or Tschumi to highlight the need to study a broader range of parameters (territorial, political, psychological, social etc.) and interactions beyond the purely formal ones, to ensure alignment between the urban planning discipline and the on-going urbanisation processes. Traditional urban planning focused on the production of rigid proposals, organizing objects and functions, and seeking to reinstate in a certain way a lost stability, instead of evolving and adapting to the instability of today´s spaces and structures (Cosgrove, 2002).

One of the parameters that growingly affect cities' comfort is urban heat accumulation. The temperature difference between the urban environment and its immediate rural surroundings is (Bohnenstengel et al., 2011) defined as the Urban Heat Island (UHI). Several studies analyse the UHI in cities such as London, Paris (Pal et al., 2012; Lac et al. 2013) or Pune (Pal & Devara, 2012). There is an increasing awareness of the impact of urban heat on health and comfort of the population (Rydin et al., 2012). In the framework of the Dutch research program Climate Proof Cities, the authors were assigned with the task to develop urban design guidelines to improve the adaptation of cities and regions to urban heat accumulation.

The research questions for this particular study were:

- How can we incorporate climatologic parameters, such as urban heat, in future urban planning processes?

– How can we ensure that the mitigation proposals are accurate enough to prevent heat accumulation and open enough to ensure they are compatible with other urban planning priorities?

In order to come up with renewed urban planning mapping strategies and tools, the first part of this study reflects on the mapping processes connected to the original nature of urban planners activity – which somehow falls in between the artistic creation and the scientific assessment – then illustrates the diversity of the parameters affecting contemporary practice – which are mainly environmental and digital – and finally identifies relevant indicators and mapping instruments to represent urban heat accumulation during heat waves. The second part of the study suggests catalysing mapping strategies -drift, layering, game-board, and rhizome (Corner, 2002) - for the integration of the urban heat into future urban planning processes.

§ 4.2 Methodology: overview of the role mapping as a design tool

§ 4.2.1 The nature of the urban planners' work

Many instruments have been developed throughout history, in order to help increase the accuracy with which the physical world that surrounds us is represented. These instruments can probably be classified into two groups: the instruments that help represent the world we perceive, and the instruments that allow visualizing the world that the bare human eye cannot grasp. Regarding the representation of the world we perceive, Nuti (Nuti, 2002) reminds that Vermeer and Saenredam consulted geodesists or surveyors to construct their paintings, while a couple of centuries later other artists used transparent glasses. In the 19th century the use of Panorama also became pretty extended. Artists were mostly concerned with the accuracy of the representation of the perceived world. In turn, it seemed that scientists were rather more concerned with the representation of the world that the human eye cannot see. Cosgrove associates this concern to modern scientific curiosity, and mentions the telescope and microscope as the most extreme examples (Cosgrove, 2002). Both artists and scientists used instruments to increase the accuracy of their representations, however the representations by artists contained comparatively a higher degree of subjectivity than those by scientists. The observation of cities by urban planners seems to fall somewhere between these two worlds. On the one hand cities and landscapes are physically perceived by the human eye, and on the other, cities are more than ever influenced by "invisible" parameters that need to be taken into consideration. The urban planner is therefore supposed to reconcile both the tangible world that shapes the cities, and the intangible parameters that influence it. Urban planners can be seen as both artists and scientists, or as Weller states (Weller, 2006) planners need to address both planning (which typically refers to mechanical systems and land-use designation) and design. Many urban planners urge for the development of new urban planning tools to update our discipline to the current times. Girot (Girot, 2006) precisely refers to the need to achieve a balance between scientific and empirical data through the development of new instruments when intervening in our cities.

The potential of mapping is somehow undervalued because many urban planners and designers still believe in the undisputed neutrality of maps, which makes them perceive mapping as a systematic action, consisting merely of the automatic translation of data into drawings, thus missing the opportunity to explore its unique potential. Accepting this inherent "opacity" and subjectivity should not detract the value of maps; on the contrary, it just unfolds the endless possibilities of the tool. As Cosgrove states "mapping a priori features are scale, framing, selection and coding" (Cosgrove, 2002). Regardless of the degree of intentionality with which these actions are undertaken, the four of them are inherent to the mapping activity. They all imply decisions that alter our way of representing and interpreting a given reality, unfolding connections between dissociated elements and revealing the emergence of hidden structures (Corner, 2002).

§ 4.2.2 New parameters to be integrated in contemporary practice

Traditionally, urbanism studied shapes and land uses, which change little over time. In the 1970´s exogenous parameters started to be integrated into design, and already by then Science magazine praised the landscape architecture department of the University of Pennsylvania, founded by McHarg (McHarg, 1981) because of its multidisciplinary team, which integrated physicists, biologists, sociologists, architects, landscape designers, urban planners and territory planners. McHarg´s Design with Nature (McHarg, 1969) was actually the seed of the integration of new parameters in the design of landscapes. (We shall note that back then the polarity between the urban and the rural delimitated very clearly the field of action of urban planners and the one of landscape architects), overlapping wildlife habitats, with geological landmarks, water-table constraints or scenic value into the design guidelines. In the 1990s Corner took over McHarg´s legacy with a less guided approach towards the integration of disciplines, generating a set of inspiring and revealing maps during his aerial trip with MacLean, which actually culminated in the production of the book "Taking measures Across the American Landscape" (Corner, 1996). In parallel, Deleuze & Guattari (Deleuze and Guattari, 1987) reflected on the dynamism of the processes influencing the lives in cities.

In the present days new instruments need to be explored in order to be able to assess the two main changing realities that characterize the post-industrial world, which according to Shane are the technological and the ecological ones (Shane, 2006). Grimm N.B. et al. stress the need to incorporate geological, ecological, climatic, social and political data, to describe and understand urban functioning (Grimm et al., 2000). Girot refers to the invisible "natural substrate of the sites" and more specifically mentions the natural water flows (covered or diverted), the erased topographies or the fragmentation of forests (Girot, 2006). Cities have started to be considered as dynamic, living organisms. Ridd & Hipple refer to cities as ecosystems, and as such they identify the energy and moisture fluxes as the main drivers of their activity (Ridd and Hipple, 2006). They use remote sensing to investigate parameters such as anthropogenic energy or the percentage of imperviousness of surfaces, parameters that affect these two balances. Aligned with this dynamic concept of cities, Acebillo refers to the urban metabolism and studies parameters such as energy consumption, waste emissions or mobility matrixes (Acebillo et al., 2012). Chao et al. (Chao et al, 2010) have produced a review of the evolution of the urban climatic maps which propose urban planning guidelines based on parameters that range from thermal imagery to topographic maps, land use maps, urban air paths, emission maps… By means of energy potential mapping, or heat mapping, Broersma tracks city's heat characteristics; these can be represented by layered maps or three-dimensional images (Broersma et al., 2013). Their heat map of Rotterdam maps the heat demand and yield potential. Van der Hoeven F. and Wandl A. mapped air and land surface temperatures, the components of the surface energy balance, as well as social and physical factors that contribute to the vulnerability of the urban population for urban heat (Van der Hoeven and Wandl, 2015). Other urban planners have started to study a wide range of statistics concentrating in the behaviour of citizens, crime rates, surveillance, traffic, light-switch activity (Amoroso, 2010) (Figure 4.1), or even cell phone activity (MIT, 2016) (Figure 4.2).

The incorporation of new disciplines in urban planning processes, imply not only the need to study, analyse and interpret new parameters but also the need to understand the way these evolve in space and time. The most didactic metaphor to describe this phenomenon is Weller´s "fluid field" of data, ideas and form when referring to cities and landscapes (Weller, 2006).

§ 4.2.3 Urban heat assessment

– Urban heat indicators

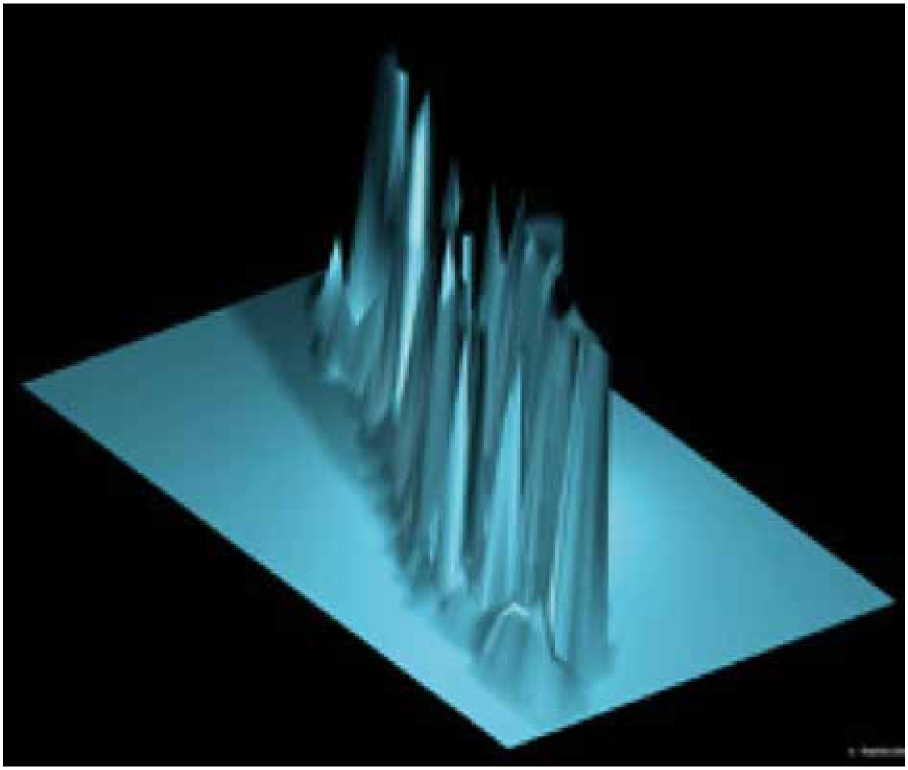

FIGURE 4.1 Densityscape, New York City, a three dimensional map depicting the super-dense residential population landscape of Manhattan Island. The exposed city: Mapping the urban invisibles. London: Routledge (Amoroso, 2010)

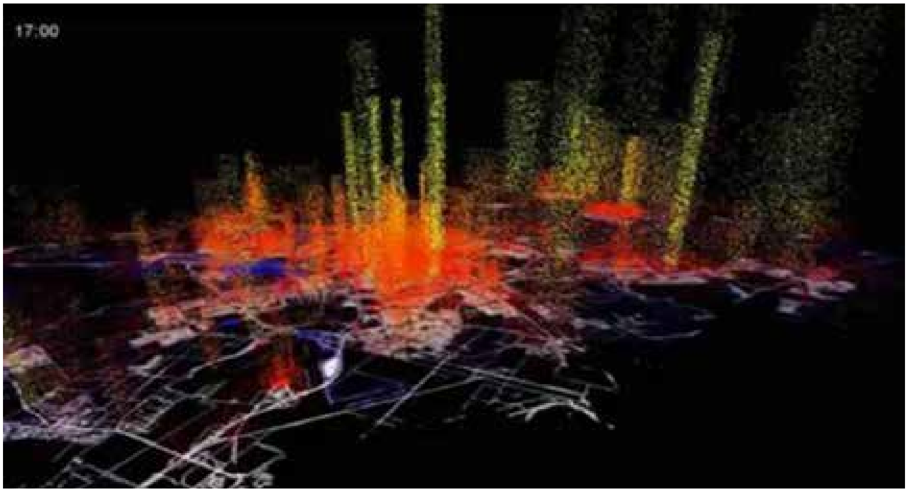

FIGURE 4.2 SMS activity at midnight, New Year´s Eve in Amsterdam (MIT, 2016).

There are two main categories of urban heat islands: the air temperature urban heat island (UHI) which concentrates in the air temperature difference and the surface urban heat islands (SUHI) which measures the surface temperature difference. They have different behaviours and patterns. The SUHI hits its peak during daytime, when the sun is still shining, reaches up to 15°C difference (EPA, 2015), whereas UHI reaches its peak after sunset, when warm urban surfaces start radiating the heat absorbed during the day towards the atmosphere, registering air temperature differences of up to 12°C. There are several studies that correlate the urban heat to the size of the cities. A linear correlation was established in 1973 by Oke between maximum urban heat island intensity and the logarithm of the population of cities in Europe and North America (Oke, 1973). In Japan and South Korea similar studies have been carried out (Park, 1986; Fukuoka, 1983). It was only after the heat wave of 2003, which caused over 80.000 deaths across Europe (Robine et al., 2007), that urban heat started to be perceived as a concern (Van Hove et al., 2011).

Air temperature seems a more relevant indicator of human comfort than surface urban heat island. However, retrieving consistent air temperature data in the urban environment is a challenge. In the particular case of the Netherlands, the KNMI meteorological stations are all located in the rural environment, precisely to erase the influence of urban heat in the temperature retrieval. With the emergence of the Internet of Things and the involvement of citizens in the gathering of scientific data new possibilities emerge. Netatmo, producer of personal weather stations gathers live data of all of its connected weather stations, to visualize it online on a scalable weather map, while allowing the data to be harvested by means of a public application (Netatmo Weathermap, 2016).

Consistent surface temperature data can also be mapped using satellite imagery. Even though the spatial pattern of UHI and SUHI differs (Dousset and Gourmelon, 2003), many climatologists use land surface temperature to assess the urban heat accumulation behaviour (Price, 1979; Roth et al., 1989; Parlow, 2003; Van Hove et al., 2011; Yuan & Bauer, 2007; Cao et al.2010; Li et al., 2011; Zhou et al., 2011; Choi et al., 2012). Moreover, remote sensing also allows mapping parameters that influence the urban thermal behaviour, such as albedo, vegetation index, imperviousness, storage heat flux, latent heat flux and sensible heat flux.

The vegetation index can be considered as a relevant indicator for urban heat studies. Several studies show that minimum air temperatures and vegetation indexes (more specifically the normalised difference vegetation index – NDVI-) are correlated: there is a linear relationship between the difference of urban and rural NDVI and the difference of the urban and rural minimum air temperatures (Gallo et al., 1993). In rural environments, heat fluxes can be expressed as a function of the vegetation index (Choudhury et al., 1994; Carlson et al., 1995).

Albedo is an index that represents surface reflectance. It is strongly related to urban heat. Increasing the albedo of roofs and pavement reduces their surface temperatures. When a surface has an albedo of 0, it means that it doesn´t reflect any radiation whereas an albedo of 1 means that all the incoming radiation is reflected by the surface to the atmosphere. In European cities the average albedo is around 0.20 (Taha, 1997). Increasing the surface albedo from 0.25 to 0.40 could lower the air temperature as much as 4°C (Taha et al., 1988).

Imperviousness makes a strong contribution to urban heat. Imperviousness seals the surface, it prevents water from evaporating, and hinders the growth of vegetation, in this way it prevents solar radiation from being converted into latent energy. Impervious surfaces have in addition, the capacity to store heat during the daytime. The heat that is stored in this process is then released at night.

The influence of other factors such as sky view factor (SVF) does not seem to be clear. Some studies find a clear correlation between SVF and nocturnal UHI (Svensson, 2004; Unger, 2004), while in other cases the correlation is not so clear (Blankenstein & Kuttler, 2004). In any case the 3-dimensional analysis of the areas is often critical to ensure that the effect of the building radiation is also taken into consideration.

– Instrument and technology used to produce urban heat maps: remote sensing

For urban planners the principal limitation of remote sensing lies in the fact that even though aerial view provides a very comprehensive overview of cityscapes and landscapes, these must be complemented by the analysis of other tangible (street level views, pedestrian flows…) and intangible parameters (economic activity, social cohesion, …). Weller (Weller, 2006) also warns about the risks of granting excessive attention to aerial photography. However, the most important challenge for urban planners is to be able to turn these accurate and precise images into maps. Satellite imagery per se cannot be taken as true record of reality. First, the selection of scale and frame are critical and then the way in which the information is filtered and represented also plays an important role. Mastering the use of software to treat satellite imagery becomes critical for urban planners to be able to integrate these into design.

ENVI is a geospatial software designed by Exelisvis (Exelis Visual Information Solutions, 2016) to process and analyze any kind of satellite imagery. The combination of ENVI and GIS allows for the greatest integration between the available raster and vector information. There is a third type of software consistently needed to work with satellite information. These are the programs that atmospherically and geometrically correct the raw satellite imagery. The geometrical correction is needed in order to be able to transpose the information retrieved from the curved surface of the earth into a two-dimensional image. The atmospheric correction is needed because the satellites retrieve the radiation emitted by the surface of the earth through the atmosphere. The radiance retrieved is somehow distorted due to the composition of the atmosphere (humidity, chemical content). Atmospheric correction software "erase" the effect of the atmosphere from the retrieved radiance through the use of certain atmosphere composition models which vary, depending on the latitude and longitude, on the season and on whether the image captures a rural or an urban environment.

The satellite images themselves, can be downloaded through the US Geological Survey Global EarthExplorer (USGS, 2016), such as Landsat or Modis. Landsat 8 has a resolution of 100 m and Modis of 1 km. Land surface temperature, heat fluxes and albedo can be mapped using Landsat imagery (100 m resolution) and processing it in ATCOR (Atmospheric & Topographic Correction: the ATCOR Models, 2016), which allows not only completing the geometric and atmospheric correction of the images but also calculates the before mentioned parameters. Satellite imagery product Modis 11A1 (1 km resolution) contains a layer where land surface temperature (day and night averages) and albedo are already processed and calculated. In this study we have only focused in the use of open source satellite imagery which have enough resolution to assess the SUHI at a city and regional scale. There is high-resolution satellite imagery which provide a more accurate analysis, however these are not open-source.

Normalised difference vegetation index is typically used to calculate vegetation index. It can be mapped after calculating NDVI.

FORMULA 4.1.

NDVI = (NIR-VIS)/(NIR+VIS).

Where NDVI is the Normalised Difference Vegetation Index, VIS is the surface reflectance in the red region (650 nm) and NIR is the surface reflectance in the near infrared region (850 nm).

With Landsat, both NIR and VIS are bands of the satellite imagery. With Modis, NDVI is included as one of the satellite products.

The production of land surface temperature maps, vegetation index maps and albedo maps is therefore not straightforward. Urban planners have started to integrate new tools and parameters into their plans and maps, to ensure their designs address the concerns of a world in constant change. The great disparity of newly assessed features and map typologies reveals the struggle of urban planners to find means to represent and integrate new disciplines into their plans. New planning processes require updated mapping typologies that efficiently address climatic and social contemporary issues, while providing an overall spatial vision and direction.

§ 4.3 Results: Catalysing mapping strategies to suggest urban heat adaptation guidelines

Drift, layering game board and rhizome are four creative mapping strategies that have been studied as urban planning catalytic strategies first by James Corner (Corner, 2002) and further by Arie Graafland (Graafland, 2010). Even though there are some overlaps and similarities between the before mentioned mapping principles (and the practical examples used to illustrate them) each of these techniques is meant to provide different visions of existing and future urban environments and landscapes. Each of them is meant to be created by different author categories (urban planners, decision makers...), addresses different audiences (citizens, politicians...) and are meant to trigger different actions and processes (revolution, interrelate different parameters, identify main processes taking place in cities...). These four categories are used to come up with innovative ways of suggesting urban design measures to adapt existing and future urban areas to the UHI, and each of them is associated with a different phase of the urban planning process.

§ 4.3.1 Game-board: preliminary strategic analysis

Game-board is a mapping process which aims at identifying hidden driving forces which "strongly affect physical states and behaviour" and which are actually manifestations of global influences on local environments (Bunschoten, 1996). Unplanned urbanism or slums probably represent the most extreme example of the variety of factors (beyond the urban plans, regulations and policies) intervening and affecting the urbanisation process. In Bunschoten´s book "Urban Flotsam" (Bunschoten, 2001), he describes different phases to identify the "field of forces" –first chapter "proto-urban conditions"-, analyse their way of functioning -second chapter "taschenwelt", in English pocket world- and investigates ways of intervening in those on going processes –chapters three and four "taxonomy and unfolding"-. The whole process´s aim is to develop scenarios to promote and inspire negotiations between the different driving forces. Game-board is not just one more mapping procedure; it should actually be the first phase of any urban planning process. Many extraordinary spatial plans and visions never actually see the light of day because they fail to involve all "actants" (partners, agents and actor). Game-board is a strategical analysis, which is even more crucial, in the case of the implementation of design guidelines to adapt cities to urban heat. Urban heat is one of the most worrying consequences of climate change in cities, however the measures to reduce it should always be combinable and compatible with the rest of social, economic and environmental priorities defined in the spatial visions of the different municipalities. In thermal study of Midden-Delfland park´s (Echevarria Icaza et al., 2016a) the preservation and promotion of the cooling capacity of this provincial park located between Rotterdam and The Hague, could be considered as one proto-urban condition to be incorporated into the Spatial Vision of the region of South Holland (Structuurvisie Zuid-Holland, 2016) which on the one hand aims at developing the necessary infrastructure to connect the two cities, and on the other hand intends to protect and preserve the park. Echevarria et al. carried out a detailed land use assessment to come up with different design scenarios (Figure 4.3) to increase the Midden-Delfland park´s natural cooling capacity suggesting landscape interventions which are flexible and combinable with the rest of spatial planning priorities. Several urban hotspots were identified in the park´s surroundings and different design measures are proposed to increase the cooling capacity of the park areas adjacent to the hotspots. The study analyses how the average night and daytime surface temperature varies depending on the nature of the park land use (forests, cropland, grassland, water surfaces, built areas and greenhouse areas) size and shape of the patches, and the design solutions proposed to increase the cooling capacity of specific park areas are based on these conclusions.

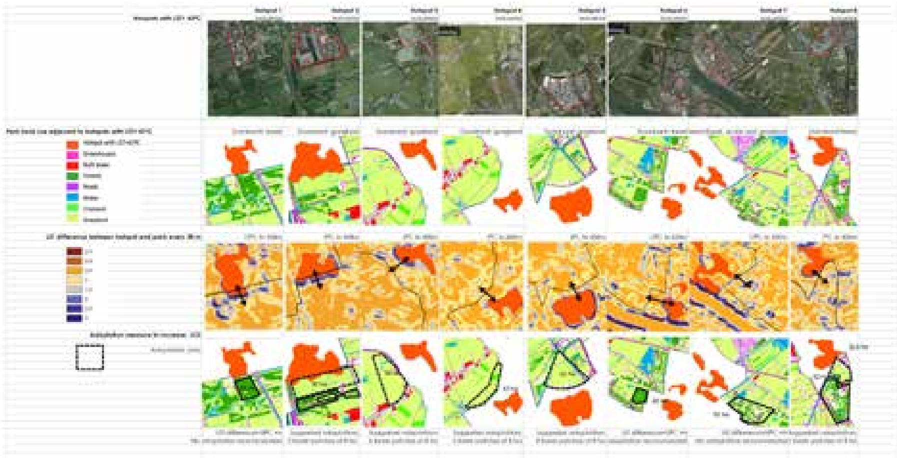

FIGURE 4.3 Diagnosis and adaptation design for hotspots with an LST>42°C (Echevarria Icaza et al., 2016a).

§ 4.3.2 Rhizome: integration schemes

The "plane of consistency" (Deleuze and Guattari, 1987) is highlighted by Corner as the core of the rhizomatic mapping, and summarized as an inclusive (of existing elements) and structuring (of new connections) plane (Corner, 2002).This representation practice can be used as a second phase of the planning process, which would take place after the game board phase. If game-board is the strategic thinking, rhizome would consist in mapping the "actants" influences, relating one with the other and suggesting open and combinable actions. In this context rhizome mapping would contain and represent not only the physical environment, but also abstract considerations, political or administrative neighbourhood boundaries, accessibility, social tendencies… identified during the game-board phase. The implementation of urban heat adaptation measures in existing cities will often require the intervention in existing urban contexts, as the sole thermal argument is most of the times by itself insufficient to justify integral neighbourhood interventions. In their study called "Surface thermal analysis of North

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Brabant cities and neighbourhoods during heat waves" (Echevarria Icaza et al., 2016b) Echevarría et al. relate conventional neighbourhood classifications (high-density city centre, city centre, pre-war neighbourhood, post-war compact neighbourhood...) –developed (among others) for housing policy implementation and created based on density, accessibility, function mix and building quality criteria- with surface thermal clusters (Figure 4.4 and Figure 4.5). Each thermal cluster comprises surfaces with specific combinations of albedo, NDVI and imperviousness, and thus specific interventions are associated to each of them for their surface temperature reduction. (Cluster 1 signature corresponds to areas with large asphalt patches. Intervention proposals to reduce surface temperature of asphalt patches would include introducing a high reflective coating, reducing the imperviousness of the surface in specific areas or introducing shades to prevent exposure to radiation). Relating the surface thermal analysis, to an existing neighbourhood classification is a way of integrating the climatologic study into the existing political, operational and administrative framework.

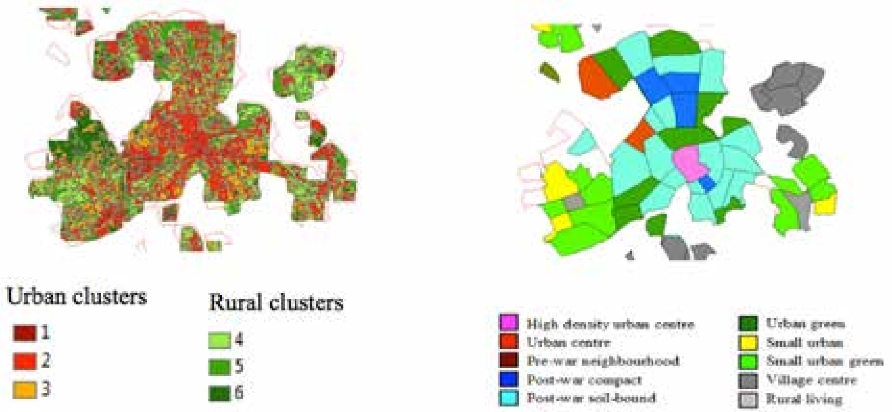

FIGURE 4.4 Compilation of LST-related maps for Eindhoven metropolitan area:Surface cover clustering and "urban living environment" categories (Echevarria Icaza et al., 2016b).

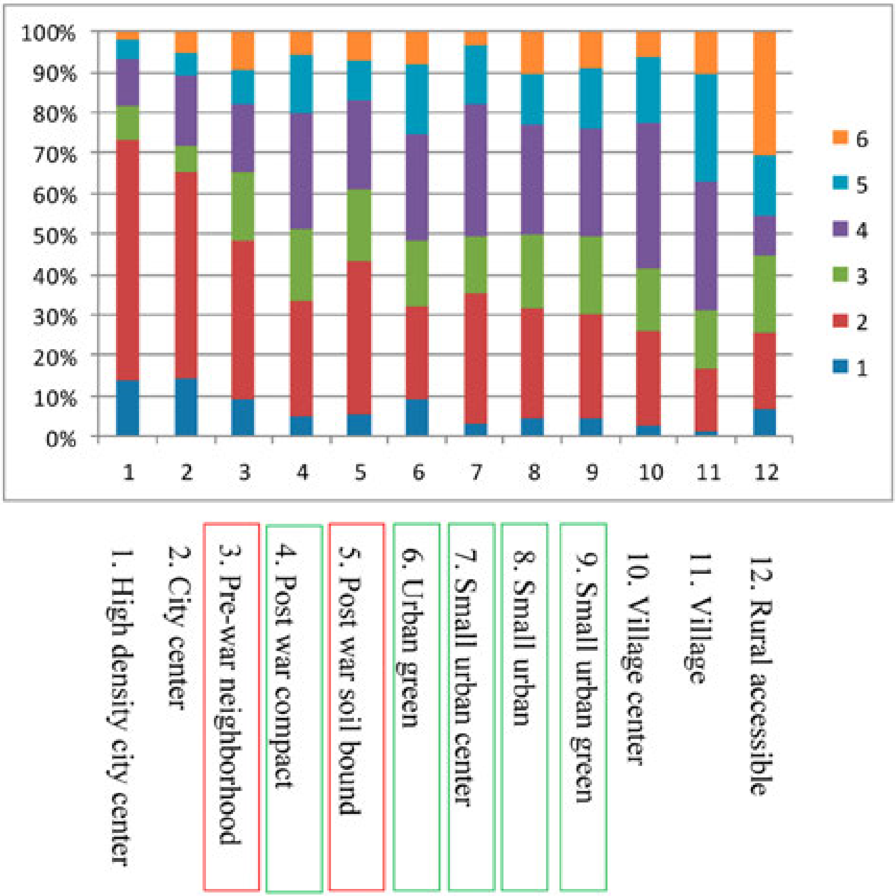

FIGURE 4.5 Surface cover cluster proportions for each of the "urban living environment" categories in the analysed medium-size cities of the North Brabant region. Neighbourhoods 3 and 5 present similar cluster proportions, and thus could be grouped. Neighbourhoods 4, 6, 7, 8 and 9 present similar cluster proportions, and thus could be grouped (Echevarria Icaza et al., 2016b).

§ 4.3.3 Layering: physical overlap

Following the rhizome mapping which represents the integrative representation of existing and proposed urban planning conditioning and determining factors, we would suggest introducing the layering phase. Layering consists of the physical overlap of different structures over a common territory. In the context of this study, layering corresponds to a more concrete activity than rhizome. The main difference between these two mapping principles is that layering integrates mainly physical parameters. Layering is an appropriate mechanism to represent different heat reduction options for one particular urban area since there are several mechanisms to reduce urban heat and the selection of these depends on many other factors. Echevarria et al. (Echevarria Icaza et al., 2016 c) (Figures 4.6, 4.7, 4.8, 4.9, 4.10 and 4.11) map different temperature related parameters for several Dutch cities. Figure 6 presents the results obtained for the city of The Hague. The storage heat flux mapping (Figure 4.6.1) is used to identify hotspot areas, these are areas that tend to accumulate heat throughout the day, and that are likely to release it at night. Thus these are areas where to concentrate design adaptation efforts. Figure 4.6.4 represents day land surface temperature, higher LST mainly correspond to industrial areas, which warehouses could benefit from flat roof cooling measures, consisting primarily of the introduction of high reflection coatings. Figure 4.6.3 shows vegetation maps, and identifies in white, the areas with a total lack of green. Greenery can always be implemented at street and roof level, however it requires a deeper assessment, as both implementation and maintenance are critical for the survival of the introduced species. Figure 4.6.5 maps albedo and allows identifying areas with low surface reflection, figure 4.6.7 and figure 4.6.8 represent the quantification of specific material surfaces which allow estimating the heat mitigation effect of the replacement of low albedo materials by higher albedo materials. The coolspot maps (Figure 4.6.10, which maps the storage heat flux in rural environments), together with the heights map (Figure 4.6.9) and the sky view factor map (Figure 4.6.12), allow identifying potential cool wind corridors (Figure 4.6.11) that would promote the natural fresh air circulation from coolspots to hotspots. Finally the “life quality map” (Figure 4.6.6) (Leefbaarometer, 2014) introduces a layer of combined physical and social parameters which is used by the Dutch Ministry of the Interior and Kingdom Relations to assess the municipalities´ quality of life.

This set of heat related layers can be overlapped, combined and filtered by urban planners with other discipline´s layers in order to produce integrating urban plans.

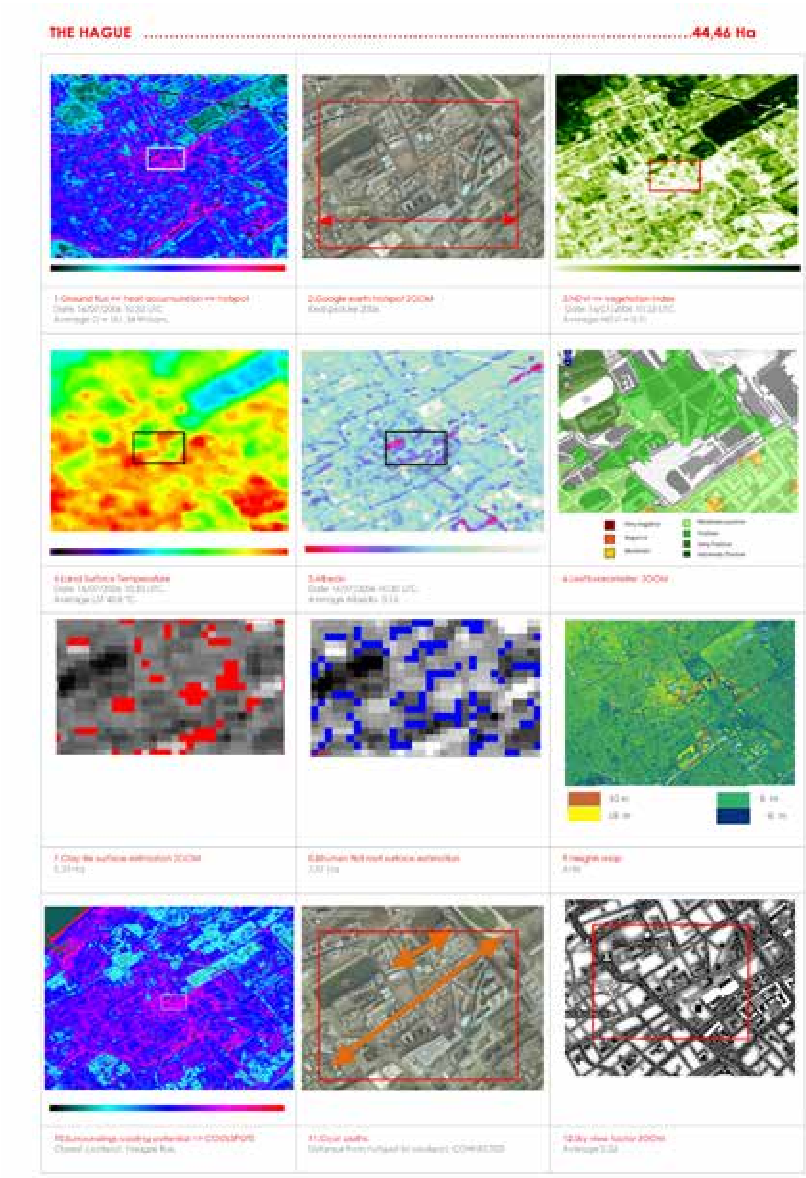

FIGURE 4.6 Modified from layers for the urban heat assessment of the city of The Hague (Echevarría Icaza et al., 2016 c)

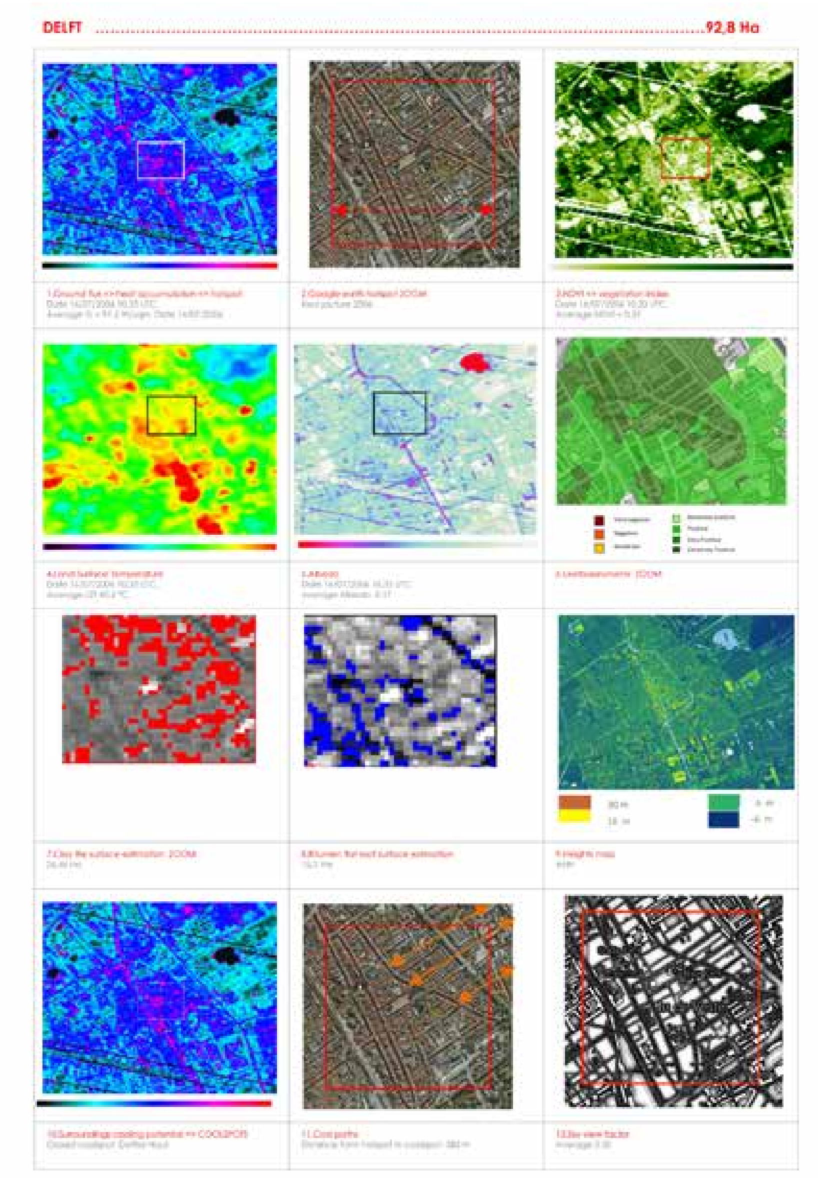

FIGURE 4.7 Modified from layers for the urban heat assessment of the city of Delft (Echevarría Icaza et al., 2016 c)

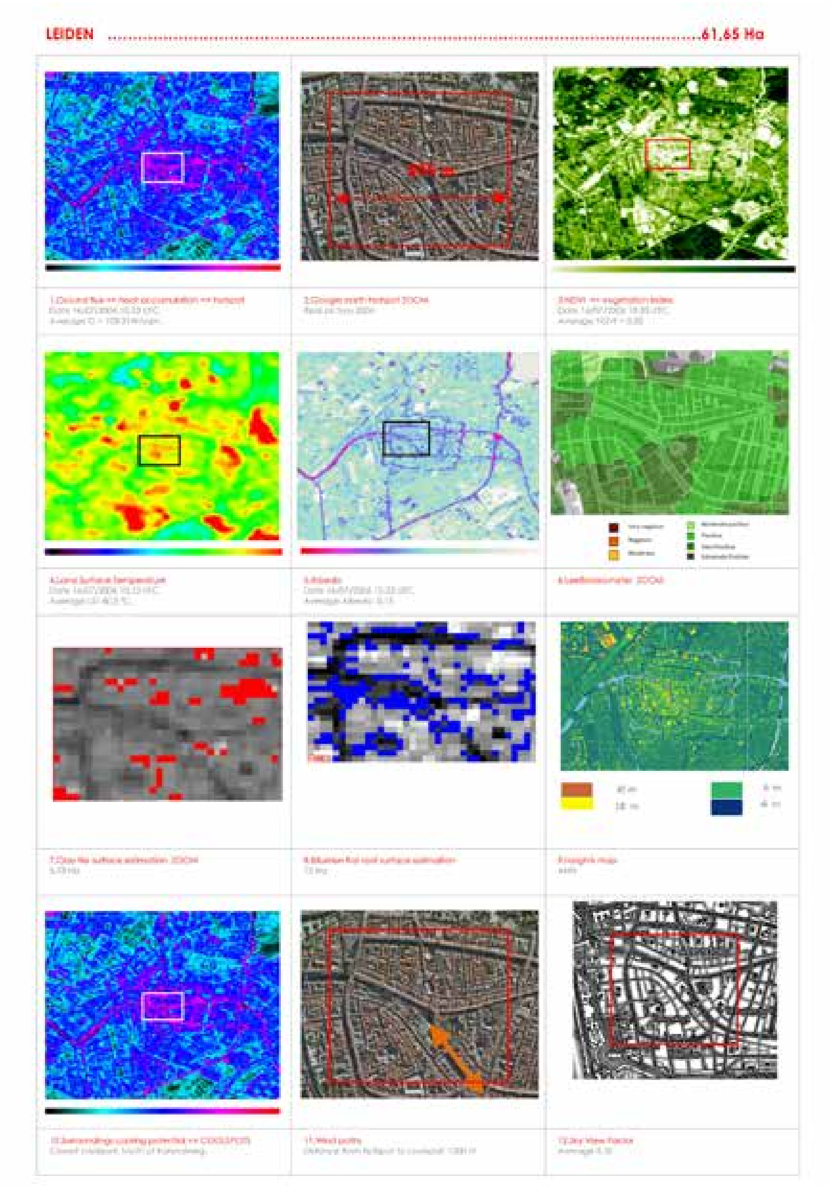

FIGURE 4.8 Modified from layers for the urban heat assessment of the city of Leiden (Echevarría Icaza et al., 2016 c)

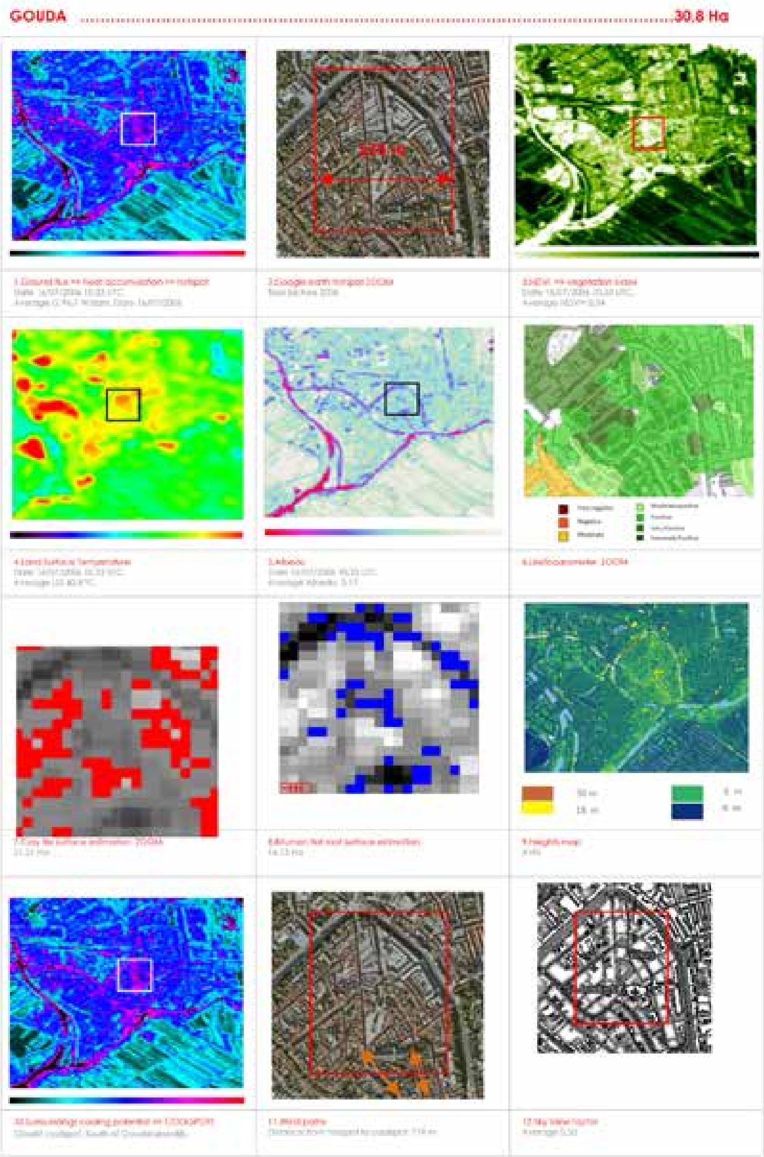

FIGURE 4.9 Modified from layers for the urban heat assessment of the city of Gouda (Echevarría Icaza et al., 2016 c)

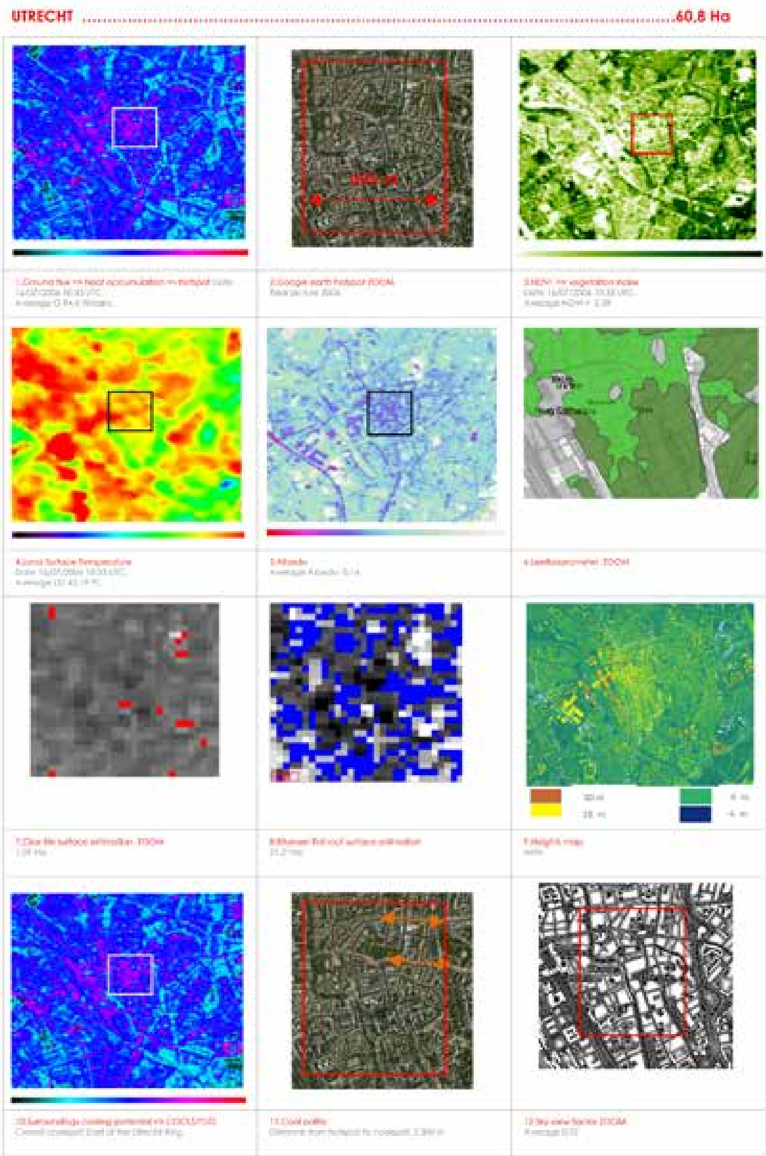

FIGURE 4.10 Modified from layers for the urban heat assessment of the city of Utrecht (Echevarría Icaza et al., 2016 c)

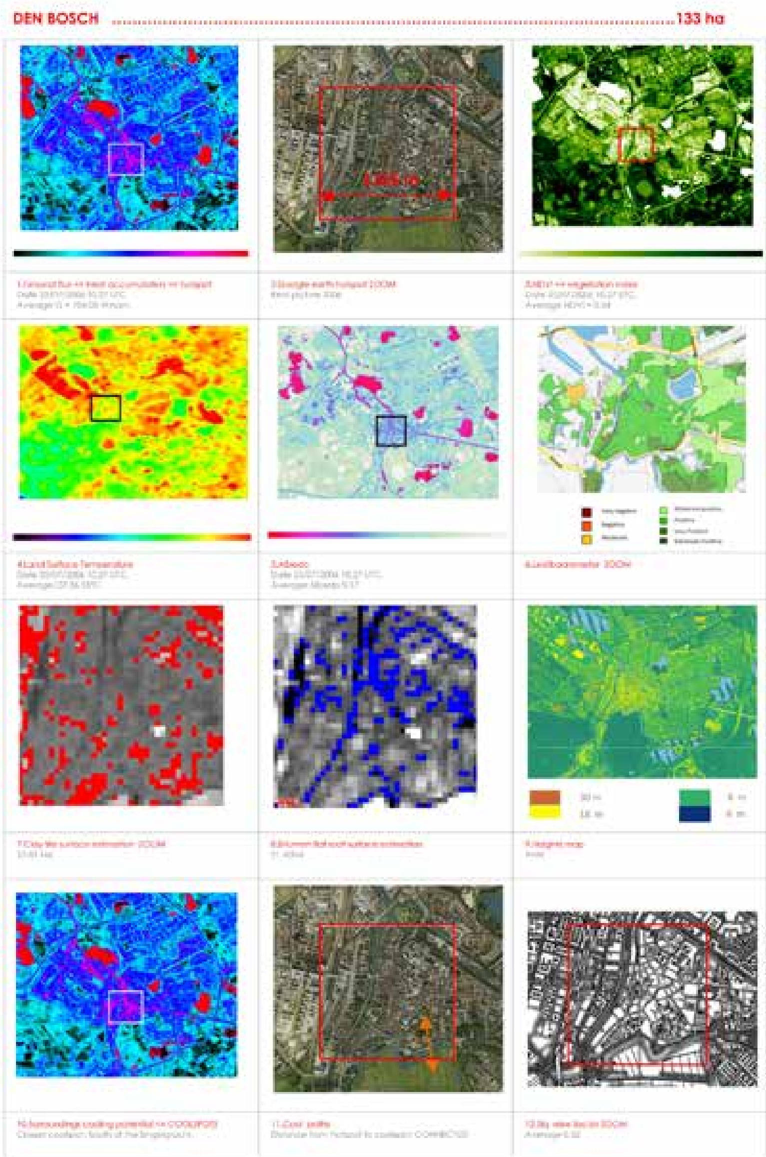

FIGURE 4.11 Modified from layers for the urban heat assessment of the city of Den Bosch (Echevarría Icaza et al., 2016 c)

§ 4.3.4 Drift

The concept of drift was originally introduced by the situationists and the main driver of this mapping category was a political one, which aimed at actually empowering the working class to promote a revolution. Corner uses the work of the situationists and of Richard Long (Knabb, 1981; Hollevoet et al., 1992; Long, 1994; Fuchas, 1986), to illustrate the drift concept, which emphasises the importance of how the user experiences the city. Data collection was done through the city walks, and the actual data collected consisted of the urban scenes perceived and experienced during those pedestrians' itineraries. However, the authors of these journey guides were not random citizens, but instead some sort of super head (Graafland, 2010)-not necessarily urban planners- aiming at restoring a lost social justice bringing back the public space to citizens. The scale of this assessment was done at street and neighbourhood level. Even though the nature of these maps was actually political, the essence of this mapping category is to guide citizens through the city public spaces. A certain parallelism can be found between this mapping category and the existing mobile phone applications containing GPS and guiding unequivocally 21st century pedestrians through cities in their search for public transportation directions and schedules, identification of specific commercial information…. However, a deeper analysis reveals that these mobile applications can precisely be very limiting depending on how they are used. The most extreme case would be to use them as a subway map, allowing an efficient circulation through its corridors without any reference or connection to the surrounding environment, which precisely represents the opposite of the drift´s aim. Thus mobile applications can be useful tools if they are used to guide us through cities, but also if they encourage us to discover and experience unexpected situations throughout the city, thus if they promote the interaction between citizens and with surrounding environment. Drift mapping could for example provide street level temperatures to guide pedestrians to fresher public areas during hot summer days. The parameter actually mapped would be storage heat flux using satellite imagery retrieved during previous heat waves, and it would be overlapped in GIS with squares, parks and streets to create routes to guide pedestrians to cooler open space areas. Echevarría et al. 2016 (Echevarria Icaza et al., 2016c) carried out the hotspots, coolspots and wind corridor analysis for the Dutch cities of The Hague, Delft, Leiden, Utrecht, Den Bosch and Gouda. Where several high level arrows suggest the direction to follow in order to reach cooler areas during heat waves (Figure 4.12).

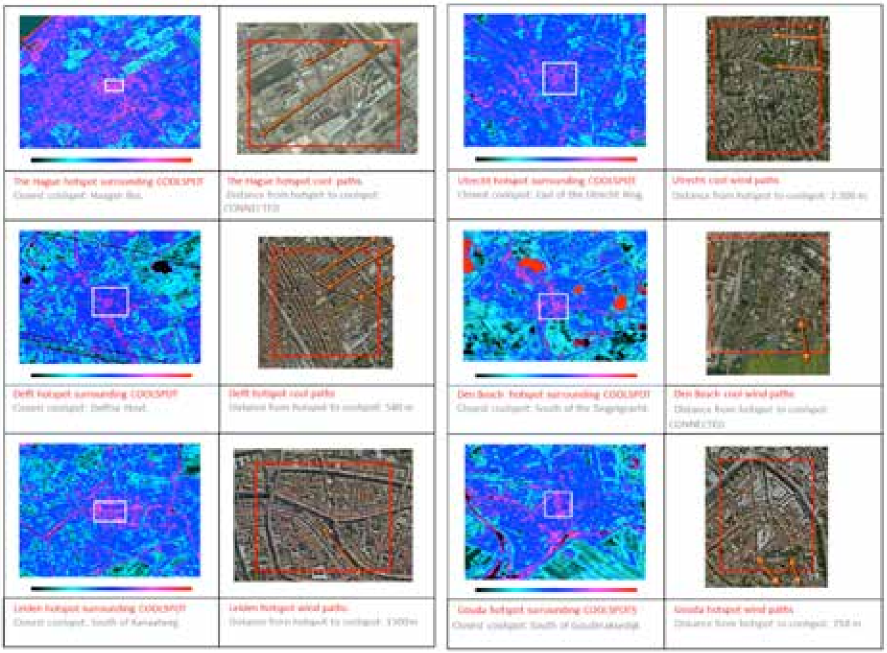

FIGURE 4.12 Comparative hotspot, coolspot, and wind corridor analysis for the Dutch cities of The Hague, Delft, Leiden, Utrecht, Den Bosch, and Gouda (Echevarria Icaza et al., 2016c)

§ 4.4 Conclusion

Even though urban planners should aim at producing integrating plans, the urban planner cannot be an expert in all disciplines of mobility, sociology, economy, climatology… The urban planner needs to be able to retrieve input from different experts, and build up integrating proposals from there. In principle, the urban planner should not necessarily have a specific command of the tools used by climatologists, sociologists, transportation engineers, … However, some of the instruments used for the assessment of those specific disciplines, have proven to have wider applications, which can be used for a more general assessment by urban planners. It is the case of remote sensing, which is often used by climatologists, to study in depth the Urban Heat Island (for example) phenomenon, but which can also be used by urban planners for a more superficial assessment of the phenomenon, more oriented towards the development of design adaptation guidelines, rather than focusing in the accuracy of the retrieved measurements. Remote sensing, combined with GIS not only provides information on the distribution of heat, it can also calculate gradients, provide urban classification maps based on thermal behaviour and vegetation density assessment, calculate the influence of the size of an urban core in its overall surface temperature, identify locations with albedo (reflectance) below a certain threshold, identify coolspots and their land uses… The applications are manifold. The maps of urban planners need to give answers to specific questions that can often be answered using satellite imagery. The depth and accuracy of the climatological assessment produced by urban planners is inevitably not comparable to the ones issued by climatological experts. In that sense it is important to remind the different purposes of these two disciplines. Climatologists aim at having the most accurate insight of the phenomena themselves, while the focus of urban planners is in developing design guidelines to reduce the effect of the phenomena and that are flexible and compatible with other urban planning priorities. The use that those two disciplines make of certain tools is therefore not the same.

§ 4.5 Discussion

In order to be able to incorporate critical climatologic parameters, (such as urban heat) in future urban planning processes it is important first to identify relevant indicators affecting the studied phenomena, then to understand the instruments needed to map the indicators and finally to choose the scale, frame and representation code to visualize best the information and to ensure that the output can be integrated into catalysing mapping categories drift, layering, game-board and rhizome.

For the integration of the urban heat assessment in the urban planning processes, the heat fluxes, the land surface temperature, the albedo, the NDVI and imperviousness have been proved to be relevant. The instruments used to map these parameters are satellite images, treated with specific geospatial software (such as ENVI), vector analysis software (Geographic Information Systems – GIS) and atmospheric and geographic correction software (such as Modtran or Atcor). Urban planners need to reinterpret the use of these powerful tools in order to ensure they do not lead to static prescriptions, but instead they need to reveal inspiring connections and information, which triggers interactions between actants, parameters and systems.

The incorporation of these parameters and tools into open and integrative urban plans can be done through the use of the before mentioned catalysing mapping categories, which can be used in a particular order during the urban planning process. Since urban heat is often not the only priority to be addressed during the planning process, the need to find integrative and catalysing mapping strategies becomes even more crucial. Game-board is the strategical analysis to be carried out in order to understand which are the "driving forces" affecting the process, rhizome is used to define the representation of all aspects (including abstract considerations) that condition the process, layering describes the mapping phase which displays the overlap the different strategies that could be used to reduce urban heat, and finally drift is used as a tool to guide citizens to fresher areas during heat waves.

References

ACEBILLO, J.; SASSI, E.; MARTINELLI, A.; LEE, I.C.; VISMARA, F.; FILIPPONI, L. A New Urban Metabolism. Mendrisio, Switzerland, USI-Universita della Svizzera Italiana, 2012.

AMOROSO, N. The Exposed City: Mapping the Urban Invisibles. Routledge: London, UK, 2010.

Atmospheric & Topographic Correction: the ATCOR Models. Available online: *http://www.rese.ch/products/atcor/* (accessed on 1st February 2016).

BLANKENSTEIN, S.; KUTTLER, W. Impact of street geometry on downward longwave radiation and air temperature in an urban environment. In Meteorol. Z., 15, 2004. 373–379.

BOHNENSTENGEL, S.I.; EVANS, S.; CLARK, P.A.; BELCHER, S.E. Simulations of the London urban heat island. In Quarterly Journal of the Royal Meteorological Society, 137, 2011. 1625–1640.

BROERSMA, S.; FREMOUW, M.; DOBBELSTEEN, A. Energy Potential Mapping—Visualising Energy Characteristics for the Exergetic Optimisation of the Built Environment. In Entropy, 15, 2013. 490–510.

BUNSCHOTEN, R. CHORA: Proto-Urban Conditions and Urban Change. In Archit. Des., 66, 1996. 16–21.

BUNSCHOTEN, R. Urban Flotsam. Rotterdam, The Netherlands, 010 Publishers, 2001.

CAO, X.; ONISHI, A.; CHENA, J.; IMURA, H. Quantifying the cool island intensity of urban parks using ASTER and IKONOS data. In Landscape and Urban Planning, 96, 2010. 224–231.

CARLSON, T.N.; CAPEHART, W.J.; GILLIES, R.R. A new look at the simplified method for remote sensing of daily evapotranspiration. In Remote Sensing of Environment, 54, 1995. 161–167.

CHAO, R.; NG, E.Y.; LUTZB, K. Urban climatic map studies: a review. In International Journal of Climatology, 2010. doi:10.1002/joc.2237.

CHOI, H.; LEE, W.; BYUN, W. Determining the Effect of Green Spaces on Urban Heat Distribution Using Satellite Imagery. In Asian Journal of Atmospheric Environment, 6, 2012. 127–135.

CHOUDHURY, B.J.; AHMED, N.U.; IDSO, S.B.; REGINATO, R.J.; DAUGHTRY, C.S.T. Relations between evaporation coefficients and vegetation indices studied by model simulations. In Remote Sensing of Environment, 50, 1994. 1–17.

CORNER, J. The Agency of Mapping: Speculation, Critique and Invention. In Mappings. Reaction: London, UK, Ed. Cosgrove, D., 2002. 213–252.

CORNER, J.; MACLEAN, A.S. Taking Measures across the American Landscape. New Haven, CT, USA, Yale University Press, 1996.

COSGROVE, D. Introduction: Mapping Meaning. In Mappings. Reaction: London, UK, Ed. Cosgrove, D., 2002. 1–23.

DELEUZE, G.; GUATTARI, F. A Thousand Plateaus: Capitalism and Schizophrenia. Minneapolis, MN, USA, University of Minnesota Press, 1987.

DOUSSET, B.; GOURMELON, F. Satellite multi-sensor data analysis of urban surface temperatures and land cover. ISPRS J. Photogramm. In Remote Sensing of Environment, 58, 2003. 43–54.

ECHEVARRIA ICAZA, L.; VAN DEN DOBBELSTEEN, A.; VAN DER HOEVEN, F. Using satellite imagery analysis to redesign provincial parks for a better cooling effect on cities. The case study of South Holland. Publisher: TU, Delft, The Netherlands, In Research in Urbanism Series IV, 2016a. (*http://rius.tudelft.nl/index.php/rius/about*).

ECHEVARRIA ICAZA, L.; VAN DEN DOBBELSTEEN, A.; VAN DER HOEVEN, F. Surface thermal analysis of North Brabant cities and neighborhoods during heat waves. In J. Land Use Mobil. Environ., 9, 2016b.
ECHEVARRIA ICAZA, L.; VAN DEN DOBBELSTEEN, A.; VAN DER HOEVEN, F. The Urban Heat Island Effect in Dutch City Centers: Identifying relevant indicators and first explorations. In Implementing Climate Change Adaptation in Cities and Communities. LEAL FILHO, W., ADAMSON, K., DUNK, R., AZEITEIRO, U.M., ILLINGWORTH, S., ALVES, F., Eds.; Springer International Publishing AG: Cham, Switzerland, 2016c.
Exelis Visual Information Solutions. Available online: *https://www.exelisvis.com/ (accessed on 1st February 2016).*
FUCHS, R.H. Richard Long. London, UK, Thames and Hudson, 1986.
FUKUOKA, Y. Physical climatological discussion on causal factors of urban temperature. In Mem. Fac. Integr. Arts Sci., 8, 1983. 157–178.
GALLO, K.P.; MCNAB, A.L.; KARL, T.R.; BROWN, J.F.; HOOD, J.J.; TARPLEY, J.D. The use of NOAA AVHRR data for assessment of the urban heat island effect. In Journal of Applied Meteorology and Climatology, 32, 1993. 899–908.
GIROT, C. Vision in Motion: Representing Landscape in time. In The Landscape Urbanism Reader. Princeton Architectural Press: New York, NY, USA, Ed. Waldheim, C., 2006. 69–85.
GRAAFLAND, A. Understanding the Socius through Creative Mapping Techniques. In Phd & Masters Reader. Delft, The Netherlands, Delft School of Design, 2010.
GRIMM, N.B.; GROVE, J.M.; PICKETT, S.T.A.; REDMAN, C.L. Integrated approaches to long-term studies of urban ecological systems. In BioScience, 50, 2000. 571–584.
HOLLEVOET, C.; JONES, K.; NYE, T. The Power of the City: The City of Power. New York, NY, USA, The Whitney Museum, 1992.
KNABB, K. Situationist International Anthology. Paul Avrich Collection (Library of Congress). Bureau of Public Secrets: Berkeley, CA, USA, 1981.
LAC, C.; DONNELLY, R.P.; MASSON, V.; PAL, S.; RIETTE, S.; DONIER, S.; QUEGUINER, S.; TANGUY, G.; AMMOURA, L.; XUEREF-REMY, I. CO2 Dispersion modelling over Paris region within the CO2-MEGAPARIS project. In Atmospheric Chemistry and Physics, 13, 2013. 4941–4961.
LEEFBAAROMETER. Ministrie van BuitenlandseZaken en Koninkrijksaangelegenheden. Available online: *http://www.leefbaarometer.nl* (accessed on 29 July 2014).
LI, J.; SONG, C.; CAO, L.; ZHU, F.; MENG, X.; WU, J. Impacts of landscape structure on surface urban heat islands: A case study of Shanghai, China. In Remote Sensing of Environment, 115, 2011. 3249–3263.
LONG, R. Kunstammlung Nordrhein Westfalen. Dusseldorf, Germany, 1994.
MASSACHUSSETS INSTITUTR OF TECHNOLOGY (MIT). Senseable Lab. Available online: *http://senseable.mit.edu* (accessed on 1st February 2016).
MCHARG, I. Human ecological planning at Pennsylvania. In Landscape and Urban Planning, 8, 1981. 109–120.
MCHARG, I.L. American Museum of Natural History. Design with Nature. Garden City, NY, USA, Published for the American Museum of Natural History by the Natural History Press, 1969.
Netatmo weathermap. Available online: *https://www.netatmo.com/es-ES/weathermap* (accessed on 1st February 2016).
NUTI, L. Mapping Places: Chorography and Vision in the Renaissance. In Mappings. Reaction: London, UK, Ed. Cosgrove, D., 2002. 90–108.
OKE, T.R. City size and the urban heat island. In Atmospheric Environment, 7, 1973. 769–779.
PAL, S.; DEVARA, P.C.S. A wavelet-based spectral analysis of long-term time series of optical properties of aerosols obtained by lidar and radiometer measurements over an urban station in Western India. In Journal of Atmospheric and Solar-Terrestial Physics, 84-85, 2012. 75–87.
PAL, S.; XUEREF-REMY, I.; AMMOURA, L.; CHAZETTE, P.; GIBERT, F.; ROYER, P.; DIEUDONNÉ, E.; DUPONT, J.C.; HAEFFELIN, M.; LAC, C.; et al. Spatio-temporal variability of the atmospheric boundary layer depth over the Paris agglomeration: An assessment of the impact of the urban heat island intensity. In Atmospheric Environment, 63, 2012. 261–275.
PARK, H.S. Features of the heat island in Seoul and its surrounding cities. In Atmospheric Environment, 20, 1986. 1859–1866.
PARLOW, E. The Urban Heat Budget Derived from Satellite Data. In Geographica Helvetica, 58, 2003. 99–111.
PRICE, J.C. Assessment of the urban heat island effect through the use of satellite data. In Monthly Weather Review, 107, 1979. 1554–1557.

RIDD, M.K.; HIPPLE, J.M. Remote Sensing of Human Settlements. 3rd ed., Manual of Remote Sensing, American Society of Photogrammetry and Remote Sensing: Bethesda, MD, USA, 2006. Volume 5, 752.

ROBINE, J.M.; CHEUNG, S.L.; LE ROY, S.; VAN OYEN, H.; HERRMANN, F.R. Report on Excess Mortality in Europe during Summer 2003 (EU Community Action Programme for Public Health, Grant Agreement 2005114). 2007. Available online: *http://ec.europa.eu/health/ph_projects/2005/action1/docs/action1_2005_a2_15_en.pdf* (accessed on 1st February 2016).

ROTH, M.; OKE, T.R.; EMERY, W.J. Satellite-Derived Urban Heat Islands from Three Coastal Cities and the Utilization of such Data in Urban Climatology. In Remote Sensing of Environment, 10, 1989. 1699–1720.

RYDIN, Y.; BLEAHU, A.; DAVIES, M.; DÁVILA, J.D.; FRIEL, S.; DE GRANDIS, G.; GROCE, N.; HALLAL, P.C.; HAMILTON, I.; HOWDEN-CHAPMAN, P.; et al. Shaping cities for health: Complexity and the planning of urban environments in the 21st century. In Lancet, 379, 2012. 2079–2108.

SHANE, G. The Emergence of Landscape Urbanism. In The Landscape Urbanism Reader. Princeton Architectural Press: New York, NY, USA, Ed. Waldheim, C., 2006. 69–85.

SVENSSON, M.K. Sky view factor analysis—Implications for urban air temperature differences. In Meteorological Applications Journal, 11, 2004. 201–211.

TAHA H. Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. In Energy and Buildings, 25, 1997. 99–103.

TAHA, H.; AKBARI, H.; ROSENFELD, A.H.; HUAND, Y.J. Residential cooling loads and the urban heat island: The effects of albedo. In Building and Environment, 23, 1988. 271–283.

UNGER, J. Intra-urban relationship between surface geometry and urban heat island: review and new approach. In Climate Research, 27, 3, 2004. 253–264.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US EPA). United States Environmental Protection Agency's Office of Atmospheric Programs. Reducing Urban Heat Islands: Compendium of Strategies. Washington, DC, USA, Environmental Protection Agency, 2015.

UNITED STATES GEOLOGICAL SURVEY (USGS) EarthExplorer. Available online: *http://earthexplorer.usgs.gov* (accessed on 1st February 2016).

VAN DER HOEVEN, F.; WANDL, A. How Space Is Making Rotterdam Warmer, How This Affects the Health of Its Inhabitants, and What Can Be Done about It. Delft, The Netherland, TU Delft Architecture and the Built Environment, 2015.

VAN HOVE, B.; STEENEVELD, G.J.; JACOBS, C.; HEUSINKVELD, B.; ELBERS, J.; HOLTSLAG, B. Exploring the Urban Heat Island Intensity of Dutch Cities; Assessment Based on a Literature Review, Recent Meteorological Observations and Datasets Provided by Hobby Meteorologists. Alterra: Wageningen, The Netherlands, Alterra Report, 2011.

WELLER, R. An Art of Instrumentality: Thinking through Landscape Urbanism. In The Landscape Urbanism Reader. Princeton Architectural Press: New York, NY, USA, Ed. Waldheim, C., 2006. 69–85.

YUAN, F.; BAUER, M.E. Comparison of impervious surface area and Normalised difference vegetation as indicators of surface urban heat island effects in Landsat imagery. In Remote Sensing of Environment, 106, 2007. 375–386.

ZHOU, W.; HUANG, G.; CADENASSO, M. Does spatial configuration matter? Understanding the effects of land cover pattern on land surface temperature in urban landscapes. In Landscape and Urban Planning, 102, 2011. 54–63.

ZUID-HOLLAND.Structuurvisie Zuid-Holland. Available online: *http://www.zuid-holland.nl/overzicht_alle_themas/thema_ruimte/c_e_thema_roew-ruimtelijke_ordening/visieopzuidholland/c_e_thema_roew-structuurvisie_2010.htm* (accessed on 1st February 2016).